RAMPART CRATERS IN THAUMASIA PLANUM, MARS. D. Reiss[1], E. Hauber[1], B. A. Ivanov[2], G. Michael[1], R. Jaumann[1], G. Neukum[3] and The HRSC Co-Investigator Team, [1]Institute of Planetary Research, German Aerospace Center (DLR), Rutherfordstr. 2, 12489 Berlin, Germany (dennis.reiss@dlr.de), [2]Institute of Dynamics of Geospheres, Russian Academy of Science, Leninskij Prospect 38, Moscow 117979, Russia, [3]Institute for Geosciences, Freie Universitaet Berlin, Malteserstr. 74-100, 12249 Berlin, Germany.

Introduction: Many large craters on Mars exhibit ejecta blankets which are not observed on other terrestrial planets like the Moon. Their morphology is likely be caused by volatile–rich target material [e.g., 1] or possibly atmospheric effects [e.g., 2]. For a given area a certain minimum diameter exists for craters which show fluidized ejecta blankets, called the onset diameter [3, 4]. Geographic mapping showed a latitude dependence of onset diameters [5]. In equatorial regions the onset diameters are typically 4 to 7 km versus 1 to 2 km in high latitudes (50° latitude) [e.g., 6], which indicates an ice rich layer at depths of about 300 to 400 m near the equator and about 50 to 100 m at 50° latitude [5]. Studies based on high–resolution Viking imagery (40–100 m/pixel) [7] confirmed the typical equatorial onset diameters. However, localized regions in Solis and Thaumasia Plana with smaller onset diameters of 3 km have been observed [7]. Recent studies based on High Resolution Stereo Camera (HRSC) imagery revealed small onset diameter (1 km) in the equatorial plateaus surrounding Valles Marineris [8]. Rampart craters may have formed over a significant time interval and therefore reflect the ground ice depths at a given time. First age determinations of rampart craters in three equatorial regions indicate that their formation is connected to volatile-rich epochs, mostly in the early Martian history (Noachian and Hesperian) [9].

Geological context: The study region Thaumasia Planum is located south of Valles Marineris and east of Sinai and Solis Plana between 285°E to 305°E and 30°S to 18°S (Fig. 1). The region mostly consists of *older ridged plains material* (unit HNr) [10], which is similar to that of *younger ridged plains material* (unit Hr) [11], but cut by grabens and more densely cratered [10].

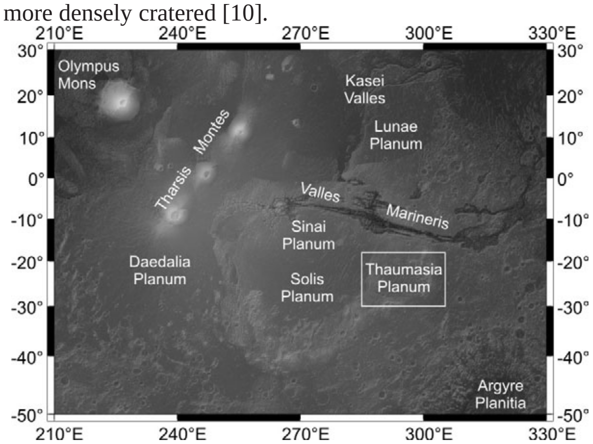

Fig. 1. Regional context (MOLA) of the study area. White frame shows the location of image mosaic in Figure 2.

Methodology: We mapped all rampart craters on the geologic unit HNr in the study region, where HRSC-coverage [12] was available. The onset diameters were measured to give some estimates about the maximum depths of the possible ground ice table: We derived the excavation depths using the depth-diameter relationship method described in [13].

To determine the absolute model ages of the rampart craters (time of the impact) we measured the crater size frequencies on the ejecta blankets utilizing the Martian impact cratering model of [14] and the coefficients of [15].

To constrain the degree of crater degradation we measured the depth (from the deepest measured point on the crater floor to the average rim height) of the rampart craters. We used Mars Orbiter Laser Altimeter (MOLA) profile data across the center of these craters.

Rampart craters: In total, 86 rampart craters were identified on the available image data in the geologic unit HNr. The crater diameter ranges from ~1 km to ~30 km (Fig. 2).

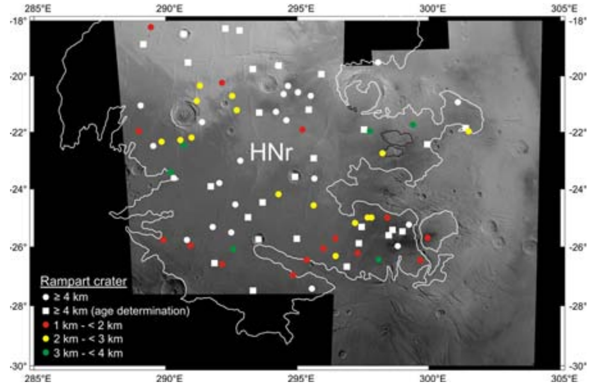

Fig. 2. Distribution of rampart craters in the Thaumasia Planum region. HRSC image mosaic (HRSC orbits 165, 438, 460, 493, 526 and 1081). Different colors show diameter classes. White line shows geological unit HNr after [10].

Onset diameter. A large number of small rampart craters with an onset diameter of 1 km occur in the Thaumasia Planum region. 30 rampart craters are smaller than the previous observed [7] onset diameter of 3 km in this region (Fig. 2). Following the approach of Barlow et al. [13], the excavation depth of the small ramparts in the study region is ~130 m (D = ~1 km). This indicates a shallow groundwater or ground-ice table in this region at the time of the impact events.

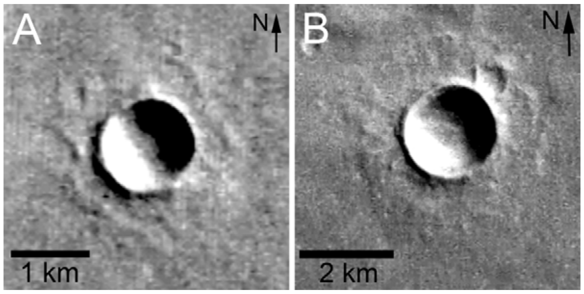

Fig. 3. Examples of small rampart craters. (A) D = 1.15 km, 296°E and 26.3°S, orbit 493; (B) D = 2 km, 299.7°E and 26.7°S, orbit 460.

Ages. The rampart craters in Thaumasia Planum show absolute model ages between ~3.75 Ga and ~3.15 Ga (D = ~4 km - ~30 km) (Fig. 4). Most absolute model ages of individual ejecta blankets are around 3.6 Ga. The ages of rampart craters coincide with the formation of the geological unit HNr at the Noachian/Hesperian boundary at around 3.7 Ga. This indicates a volatile rich period in Thaumasia Planum in the early Hesperian. However, the age of the smaller rampart craters ($\lesssim$ 5 km) can not be measured due to the small area of their ejecta blankets. Although the ejecta blankets are cratered and show some degradation, it is unclear when they were formed.

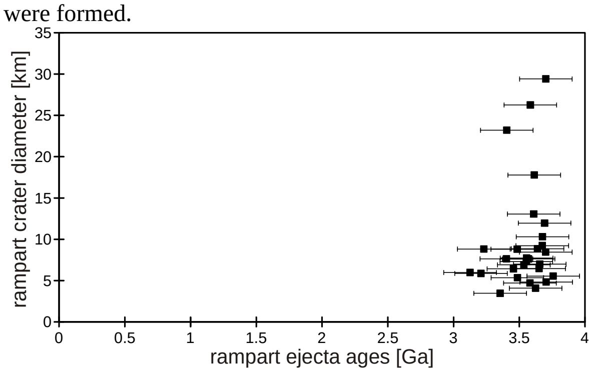

Fig. 4. Absolute model ages of rampart craters versus crater diameter. Error bars are 30% for model ages younger than 3 Gyr and ±200 Myr for model ages higher than 3 Gyr [13].

Depth-diameter ratios. The depth-diameter (d/D) ratio is one method to constrain the relative age of the small craters. The d/D relationship helps to assess erosional and infilling processes, which modified the rampart craters in comparison to fresh craters. Lower d/D ratios indicate older craters. Figure 5 shows the measured d/D ratio of rampart craters in Thaumasia Planum. In comparison to the globally derived values of the most pristine 25% of simple craters of [17] they show a lower d/D ratio. Furthermore, on average the rampart craters have a depth–diameter ratio of ~0.12 in contrast to general d/D relationships of ~0.2 for fresh simple craters [18]. This may indicate that the small rampart craters are old and were formed in the Hesperian like the larger rampart craters.

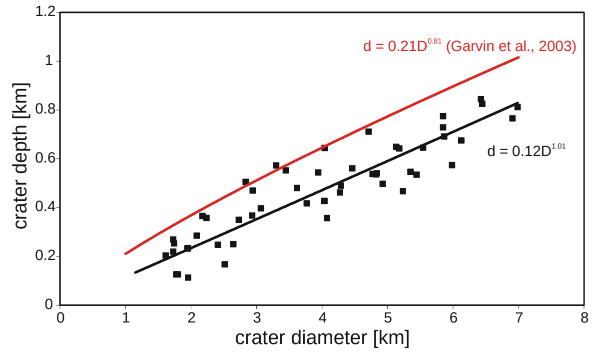

Fig. 5. Crater depth versus crater diameter for rampart craters (black squares) of the study region. A fit of the globally measured most pristine 25% of simple craters of [17] are shown for comparison (red line).

Discussion and Further Work: The first results of this study suggest that the formation of rampart craters is connected to volatile rich periods in Thaumasia Planum, possibly related to the formation of the unit HNr. The observed small onset diameter (1 km) in this equatorial region on Mars was unknown before and indicates a shallow groundwater or ground ice table at the time of the impact. In contrast to the larger Hesperian–aged rampart craters, their age is uncertain. Although the degraded morphology of the ejecta blankets and the low d/D-ratio suggest the small rampart craters are old, further work is necessary to constrain their formation time. The next steps of our analysis are 1. measuring the depth and diameters of all non-rampart craters on the HNr unit, and 2. estimating how many craters of a given size are statistically Hesperian in age and comparing the number of craters which were accumulated later under possibly dry conditions to constrain the ratio of Hesperian/post-Hesperian small rampart and non-rampart craters, and verifying that this is compatible with the flux estimate.

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